DDF Annual Report

Title of Investigation:

Diffusion-Suppressed Pixel Proportional Counter for High-Efficiency X-ray Polarimetry

Principal Investigator:

Robert Petre (Code 662)

Other In-house Members of the Team:

Phil Deines-Jones (Code 662) and Keith Jahoda (Code 662)

External Collaborators:

Kevin Black (Forbin) and C. J. Martoff (Temple University)

Initiation Year:

FY 2004

Aggregate Amount of Funding Authorized in FY 2003 and Earlier Years:

$0

FY 2004 Authorized Funding:

$50,000 and 0.2 full-time equivalent (FTE)

Actual or Expected Expenditure of FY 2004 Funding:

In-house: $42,000;
Grants: $8,000 to C.J. Martoff (Temple University)

Status of Investigation at End of FY 2004:

To be continued in FY 2005 with transition to technology development funding for the Advanced X-ray Polarimeter (AXP)

Expected Completion Date:

2006

Purpose of Investigation:

Two groups, including the Goddard Space Flight Center, have recently demonstrated the ability to measure X-ray polarization using the photo-electric effect. Polarization measurements hold the potential to distinguish, among competing models, the geometry of the X-ray emission regions in the accretion disks (orbiting gas and dust) around galactic and extra-galactic black holes and other regions where energetic processes take place. Photo-electric polarimeters can be one to two orders of magnitude more sensitive (per unit collecting area, mass, or volume) than previous polarimeters. Instruments such as these can provide interesting sensitivity within the constraints of a Small Explorer, like the Advanced X-Ray Polarimeter (AXP), proposed by Principal Investigator J. Swank. Even with this advanced technique, X-ray polarimetry still requires long observations, or more precisely, the gathering of many photons. This investigation aims to demonstrate that suitably chosen electro-negative gas additives will result in higher-sensitivity detectors, especially at high energy.

FY 2004 Accomplishments:

In FY 2004, we identified carbon disulfide (CS_2) as the most promising gas additive. CS_2 is a volatile, flammable liquid at laboratory temperatures and pressures, and requires special handling in both its liquid and gas phases. During this fiscal year, we outfitted our main laboratory with a gas-handling system that ensures safe handling and disposal of CS_2. It also facilitates the safe handling of other flammable proportional counter gases of interest, such as isobutane and dimethyl ether.

We also designed and implemented a low-noise, 12-channel readout system to directly measure lateral diffusion. This readout system can be connected to strip anodes (of varying pitch) to create a one-dimensional imaging system, capable of measuring the lateral extent of a charge cloud after drift through a variable distance. Variations in the size of the cloud as a function of drift distance can be directly interpreted in terms of the diffusion coefficient.

We successfully demonstrated this with micropattern detectors. We operated our chamber with mixtures of Ar/CS_2 and CO_2/CS_2 and demonstrated reasonable performance as measured by gas gain and energy resolution. With partial pressures at least 40 Torr of CS_2, we are certain that the charge is carried to the amplification region by negative CS_2 ions. The evidence for this is in the much slower drift times, verified by the fact that we resolve in time the individual electrons arriving at the amplification stage.

The apparent requirement that ~40 Torr (or more) of CS_2 is required may limit the usefulness of this technique below 2.5 keV, the K-shell absorption edge of sulfur, as sulfur is the dominant absorber below this energy. Because the photo-electron emission angle correlates with the photon polarization most strongly for K-shell interactions, sulfur is a poor choice of absorber below this energy. The technique remains quite promising in gas mixtures tuned to higher energies.

During FY 2004, no patents were prepared, and no professional publications or presentations were made concerning this work.

Planned Future Work:

Measurements of diffusion, and particularly as a function of amount of CS_2, were not completed in FY 2004 due to difficulties (now largely resolved) with the position-sensitive readout in our chamber. These measurements will be continued in FY 2005, supported by other funding.

Summary:

Electro-negative gas admixtures or contamination is generally regarded as an anathema to proportional counters. The innovation is the recognition that a carefully chosen and controlled electro-negative additive may provide a benefit (reduced diffusion) without the loss in efficiency and resolution generally associated with contamination by water vapor, for instance. The potential payoff to the Goddard Space Flight Center is increased sensitivity in an Explorer-class mission centered around X-ray polarization. Increased sensitivity makes such a mission more attractive during the selection process. The success criteria are to demonstrate: 1) operation with an electro-negative gas admixture; 2) a reduction in diffusion; 3) that such a mixture could be part of a long lifetime and space-qualifiable detector. The first criterion has been met. The second should be determined within FY 2005. The third, assuming that diffusion is reduced, will require careful study and lifetime tests. The risk to the third success criterion is that long-term exposure of detector components to CS_2, which has some corrosive properties, will result in degraded performance. Careful examination of detector materials and construction techniques will be required.